Achieving energy efficiency in public heritage buildings: Towards a sustainable approach to practice

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Abstract:

Heritage buildings in the UK unquestionably constitute some of the most beautiful features of the country's cityscape. The challenge is that since most of these buildings were designed and built in a very different age, they are often seen as hugely energy-inefficient. Although, numerous attempts have been made to improve their energy efficiency, however due to the impulse to protect their delicate fabric, few have achieved little or no success. This paper as part of a doctoral research into energy management in reuse of public heritage buildings (PHBs); investigate strategies adopted to improve energy efficiency in adaptive re-use of PHBs where energy use problem could potentially be addressed. An online survey was conducted among heritage building stakeholders who reported their perceptions of energy use reduction for sustainable reuse PHBs. Findings show that most respondents were less inclined in their projects to implement energy efficiency strategies. Across the survey, few respondents who had significant success had better perceptions of the sustainable approach to achieving energy efficiency for heritage buildings. The paper presented the recommendations as perceived by the stakeholders; conclude by highlighting that a well-designed efforts to improve energy efficiency in reuse PHBs would require energy management to be incorporated into the daily operational practices. This could pay greater dividends towards achieving environmental sustainability of heritage buildings with better outcomes in both heritage and energy conservation.

Keywords: *adaptive reuse, energy efficiency, energy management, public heritage buildings,*

1. Introduction

Globally, the building sector accounts for 30-40% of energy consumption, this is equivalent to 2,500 Mtoe every year [1]. While buildings in Europe account for 40-45% of energy use [2]; in the United Kingdom, existing buildings is responsible for nearly half of present CO_2 emissions: 27% from domestic and 22% of public and commercial buildings (over 100million tons of CO_2 per annum). About 40% of homes – about 8 Million – were built before 1939; half of those were constructed prior to 1919 [3]. The concern for environmental impact of buildings has giving rise to varieties of drivers and increasing energy policies and reviews for environmental sustainability of buildings in form of policies, directives, regulations, guides and incentives for energy efficiency and carbon reduction targets.

Early 2002, Energy Review produced noted the essential for improving energy efficiency in buildings with recommendations for strategy or action to deliver a phased transition to low energy buildings through the development of the Building Regulations [4]. The question regarding the creation of an Energy White Paper on "*What possible ways could encourage the owners of the existing stock of dwellings and other types of buildings to improve energy performance?"* [5] was not addressed in the Energy White Paper itself. In response to the UK Energy Review, Royal Institute of Chartered Surveyors [6] is of the opinion that "Energy review is a failed opportunity to challenge the broader and more critical issues that concerns sustainability in buildings. This paper focuses on public heritage buildings (e.g. industrial warehouse, churches etc.) in the United Kingdom originally built for a different purpose and subsequently converted to accommodate community uses.

2. Climate change and adaptation of existing buildings

The climate change agenda as an important driver for changing the way in which the built environment is produced and managed leads to increasing pressure for the existing building stock. This includes heritage buildings to incorporate measures that directly or indirectly reduce CO_2 emissions. However, heritage buildings pose special problems where compromises may be needed between maintaining the integrity of the original structure and adapting them to climate change [7]. An instance is the part L of the building regulations which excludes listed buildings and those in conservation areas. Essentially, achieving holistic sustainable management of heritage buildings requires all aspects of sustainable development to be taken into consideration. Numerous researchers [8]-[11] have posited that adaptation is an effective strategy for improving the sustainability of existing buildings along with its potential of giving extension of life to a building. The authors argued that by reusing existing buildings, lower energy consumption, material, transport and pollution can be achieved thus making a considerable contribution to sustainability.

This study is part of a wider doctoral research into energy management in reuse of PHBs; identified adaptive re-use of existing buildings where energy use problem in buildings could potentially be addressed. Among the adaptive reuse of existing buildings are public buildings of heritage value many some of which are undergoing conversion to other uses. The aim of this paper is to identify strategic and sustainable approaches for reuse of PHBs to achieve energy efficiency and the needed reduction in their carbon footprint without undermining their historical value.

3. Research method

3.1 Stakeholder's online perception survey (OPS)

Survey method was considered appropriate for this study due to the size of the population which covered the entire country and as a way to obtain standard and stable collection of data from a specific population [12]. The target respondents of the survey involved a sample of 121 practicing professionals and 90 policymakers from heritage building sector focusing on architects, conservation officers, engineers, energy consultants, planning and development control officers, and surveyors. The policymakers include; conservation officers, planning and development control officers, regulatory bodies' officers. The respondents were selected randomly across United Kingdom.

Respondents were asked to complete the sections that correspond to their role in the survey. For questions relating directly to projects implementation, respondents were asked to complete the full questionnaire; for the policymakers some questions can be left unanswered. The questionnaire contained 19 questions grouped into four sections namely: professional values and priorities for conversion projects; energy efficiency for sustainable conversion of PHB projects; perceived barriers to energy efficiency improvements to conversion projects; current practice and strategies adopted for successful energy efficiency.

The invitation to complete the survey was sent to 738 stakeholders. In total, 211 completed the survey online representing a response rate of 29 percent. Table 1 shows a breakdown of the respondents and the number of projects completed. The response rate is better than many previous studies [13] – [14] that have used survey method. The use of a questionnaire was identified as the most suitable instrument through which the respondents could be easily reached in the most economical [15] efficient and popular method to collect the required information.

Table 1: Distribution of Study Participants, professional role and number of projects

Location	Practicing Professionals	Policy makers	Total	No. of projects
England	109	72	181	2785
Scotland	10	13	23	348
Northern Ireland	1	0	1	3
Wales	1	5	6	100
Total	121	90	211	3236
	57%	43%	100%	

A structured questionnaire to determine reliably the stakeholders' perceptions was developed by the researcher incorporating 28 factors obtained from the review of relevant literature relating to energy use in PHBs. The questionnaire was first administered to a group of 35 professionals in heritage industry who were not included in the sample used for the study to obtain reliability of the instrument before it was finally administered online between May and July 2013 using SurveyMonkey platform. Reliability analysis was conducted to test the internal consistency and the scores on Cronbach's Alpha test for response indicated a score of 0.76 which exceed the accepted value for alpha at the least of 0.60 for new scales [16].

4. Analysis and Results

The analysis of the questionnaire used a combination of nonparametric techniques and descriptive statistics to determine the relative importance of sustainable strategies adoptive by the respondents using SPSS 20.0. Nonparametric statistics such as Spearman's p suits data with nominal, ordinal and interval or ratio scale of measurement [17]. To establish the sustainable approach for energy use reduction in reuse of PHBs and indicators of successful reuse projects, respondents were asked to rate on a five-point scale (1 - 'lowest' to 5 - highest) their recommendation for most sustainable option(s) for energy efficiency in conversion projects. Relative significance index (RSI) was computed based on a formula adopted from [18]. RSI is recognised as an excellent approach to aggregating and converting the scores of the variables rated on an ordinal scale making them easy to rank and preferred over other descriptive statistics such as MS or standard deviations as they present more reliable overall ranking.

$$\text{Relative significance index} = \frac{\sum w}{AN}$$

Where w is the weighting given to each factor by the respondents, ranging from 1 to 5;
A is the highest weight (i.e. 5 in the study);
N is the total number of respondents.

RSI values of the strategies adopted were obtained and compared using Spearman Rank Order correlation. The results are presented in Tables 2, 3, and 4. It can be seen from the result obtained from Table 2 that the most popularly identified strategy for energy efficiency for reuse of PHBs is "Building services upgrade" with the highest RSI value of 0.785 while the respondents ranked the least "Consideration and application of renewable technologies" with the smallest value of RSI (0.560).

Table 2: Ranking of strategies for energy efficiency in reuse of PHBs

	1	2	3	4	5	NR	RSI	Rank
Upgrading and improvement to building fabric to reduce its U-value	23	29	35	40	28	56	0.627	4
Building services upgrade	4	8	32	63	48	56	0.785	1
Consideration and application of renewable technologies	21	41	51	32	10	56	0.560	5
Incorporation of building energy management system	11	21	50	50	21	58	0.664	3
Users behaviour change	4	11	36	51	48	61	0.771	2

NR – Not Rated

A similar treatment was extended to indicators of successful conversion projects and the result is presented in Table 3.

Table 3: Ranking of indicators of successful conversion projects as perceived by respondents

	1	2	3	4	5	NR	RSI	Rank
Perform the functions well for which they are redesigned and/or converted	1	5	28	57	66	54	0.832	2
Respond well to their surroundings and enhance their context	4	6	27	66	54	54	0.804	3
Improved energy performance and carbon emissions reduction after conversion	6	23	50	54	21	57	0.679	6
Conversion is reversible and the building can be reinstated to its former use.	9	23	44	44	35	56	0.694	5
Design interventions are sympathetic with the character of the building	1	3	15	48	86	58	0.881	1
Improve users comfort	6	13	53	54	21	64	0.697	4

NR – Not Rated

It can be seen from the Table 3 that the most popularly identified indicator of successful conversion projects is "Design interventions are sympathetic with the character of the building" with the highest RSI value of 0.881 while the respondents ranked the least “Improved energy performance and carbon emissions reduction after conversion” with the lowest value of RSI (0.679). The two sets of RSI values were then subjected to Spearman Rank Order Correlation and the result is presented in Table 4.

Table 4: Relationship between sustainable options and indicators of successful reuse projects.

			RSI (1)	RSI (2)
Spearman's rho	RSI(1)	Correlation Coefficient	1.000	.500
		Sig. (2-tailed)	.	.391
		N	5	5
	RSI(2)	Correlation Coefficient	.500	1.000
		Sig. (2-tailed)	.391	.
		N	5	6

Findings from Table 4 shows that the observed correlations between sustainable options for energy use reduction and indicators of successful reuse projects shows moderate relationship; however, it is not significant to support sound decision making as the p-value (0.391) was greater than 0.05. The findings obtained from Table 2 and Table 3 was combined to determine the respondents’ priorities in their approach to addressing energy use reduction and their perception of indicators of successful reuse of PHBs.

Table 5 present the combined findings of the overall RSI and the corresponding ranking of current practice/strategies. It can be seen that the top ranks are design interventions (ranked 1st), functional performance (ranked 2nd), and the project responding to their surrounding context (ranked 3rd). It could be seen that the importance given to environmental sustainability (i.e. ‘improved energy performance’ and ‘building energy management system’) in practice is low in ranking (i.e. 7th and 9th respectively).

Table 5: Combined ranking of current practice/strategies

Current practice/strategies	Mean	SD	RSI	Rank
Design interventions are sympathetic with the character of the building	4.405	0.798	77%	1
Perform the functions well for which they are redesigned and/or converted	4.159	0.873	75%	2
Respond well to their surroundings and enhance their context	4.019	0.951	74%	3
Building services upgrade	3.923	0.977	72%	4
Users behaviour change	3.853	1.039	71%	5
Improve users comfort	3.483	0.982	67%	6
Improved energy performance and carbon emissions reduction after conversion	3.396	1.025	65%	7
Conversion is reversible and the building can be reinstated to its former use.	3.471	1.164	65%	7
Incorporation of building energy management system	3.320	1.098	64%	9
Upgrading and improvement to building fabric to reduce its U-value	3.135	1.324	59%	10
Consideration and application of renewable technologies	2.800	1.113	55%	11

To determine the most sustainable approach to achieving energy efficiency in PHB projects, the respondents were asked to suggest and recommend in the survey, strategies they adopted that have achieved success to a significant extent in improving energy efficiency in their past project. Table 6 presents the stakeholders proposed strategies and recommendations for sustainable reuse of PHBs projects and their ranking according to their relative importance quantified by the RSI method. It can be seen from Table 6 that the most prevalent strategy to achieve energy efficiency in PHBs is energy management (ranked 1st). This is closely followed by smart metering (ranked 2nd), operational energy management awareness and policy (ranked 3rd), renewable installations (ranked 4th) and other innovative strategies and building services upgrade both tied on 5th rank. The result further shows that respondents recommended "improvements to building fabric to reduce U-value" (ranked 9th) as secondary when considering energy efficiency improvements.

Table 6: Ranking of strategies / recommendations for long-term sustainability

Code	Strategies /recommendations	% of total responses	RSI	Rank
Q18_3	Energy management system	29.9%	62%	1
Q18_5	Smart metering	17.1%	60%	2
Q18_7	Operational energy management policy & awareness	32.2%	59%	3
Q18_6	Renewable installations (e.g. solar, geothermal, biomass)	36.0%	58%	4
Q6_6	Other innovative suggestions	10.4%	56%	5
Q18_2	Building services upgrade	55.5%	56%	5
Q6_3	A framework disseminating effective strategies for conversion projects	33.2%	54%	7
Q18_4	Smart lighting control	35.5%	54%	7
Q18_1	Improvements to building fabric to reduce U-value	54.0%	53%	9
Q6_2	Award schemes to promote and encourage best practice	42.7%	51%	10
Q6_1	Flexibility to building regulation requirements	50.2%	51%	10
Q6_5	Sustainability scheme for heritage buildings	41.2%	50%	12
Q6_4	Local authority supplementary guidance	32.7%	48%	13
Q18_8	Others (careful attention to air leakage; draughtproofing of windows, passive design features, secondary glazing, voltage reduction, etc.)	6.6%	48%	13

5. Discussion

The main focus of this study was to identify and establish the most sustainable strategies for achieving energy efficiency in reuse of PHB projects. Findings reveal the existence of the gap between what the respondents perceived as important in theory and what they adopt in practice. Results reveal that the respondents were overly focused on design interventions than improving energy efficiency of the projects. This partly might be due to much caution resulting from compliance with conservation policies and possibly because energy efficiency improvements are mostly seen as a barrier to the protection of the delicate fabric of heritage buildings. Thus, when it comes to heritage building projects, environmental sustainability are regarded as out-of-budget costs and, therefore, less considered.

Whilst prominence is given to building services upgrade and improvements to reducing building fabric U-value with no significant energy efficiency improvements from these strategies; energy use reduction could be achieved without any upfront costs if curtailment through energy management is incorporated into the daily operational practices. Surprisingly, findings show that those who have achieved moderate to significant improvements in energy efficiency were those who implemented energy management strategies. This view is in line with those of [19] who expressed that increasing energy efficiency through curtailing operations that consume energy could be the inexpensive options for reducing CO_2 emissions.

Respondents were also poorly attuned to understanding and employing the most effective and result oriented strategies for reducing energy consumption. As it was observed that these strategies have only been implemented by few of the respondents. Possibly, the consistent absence of priority for environmental sustainability for PHB projects in practice could partly explain the reasons for their poor energy performance. These observations are reinforced by the findings of this study indicating that some of the respondents may have been better informed than others as only a very small percentage (29.9%) have achieved significant results. However, having the knowledge and the relative importance of these strategies would allow stakeholders to make more informed decisions regarding energy efficiency.

6. Conclusions

This study identified the top influencing factors affecting energy efficiency in reuse of PHBs. Currently in practice, the leading emphasis and driver is "design interventions", "functional performance" and "project responding to their surrounding context". This study suggests that such approaches fail to recognise the key strategies to achieving environmental sustainability in reuse of

PHB projects and that better outcomes could result in both heritage and energy conservation, through energy management incorporated into the daily operational practices. From this perspective, the locus of intervention in reuse of PHBs would need to shift and be redirected from the top-down approach in current practice to strategies that facilitate, balance and accommodate both heritage and energy conservation.

In conclusion, greater attention needs to be given to understanding and managing the pattern of energy use in the building operational phase. This would need to be balanced with more coherent and strategies needed for sustainable reuse of PHBs to meet up with the challenges emanating from the climate change issue. In addition, better understanding of past energy performance of the buildings could inform the decision process by which such buildings are converted and modified to meet up with current modern energy standards. The key to achieving energy efficiency in reuse of PHBs may to a large extent, depend on facilitating these processes and making environmental sustainability to be at the core of heritage projects and as part of their long-term management.

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